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EXAMINER	
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Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 07-01)

AS-4

Office Action Summary	Application No. 09/955,297	Applicant(s) ROHR ET AL.
	Examiner Brian L. Mutschler	Art Unit 1753

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____ .

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-41 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) 1-41 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 19 September 2001 is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

11)☐ The proposed drawing correction filed on _____ is: a)☐ approved b)☐ disapproved by the Examiner.

If approved, corrected drawings are required in reply to this Office action.

12)☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

13)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____ .

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).

a) ☐ The translation of the foreign language provisional application has been received.

15)☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____ .
4) ☐ Interview Summary (PTO-413) Paper No(s). _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: .

DETAILED ACTION

Claim Rejections - 35 USC § 112

1. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

2. Claims 10-13 and 27-30 are rejected under 35 U.S.C. 112, first paragraph, because the specification, while being enabling for using InP substrates and InGaAsP or AlGaAs quantum well layers and barrier layers, does not reasonably provide enablement for other materials as substrates or strontium-containing layers. The specification does not enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make the invention commensurate in scope with these claims. The specification does not describe the use of other materials as substrates other than InP. Furthermore, InGaAsP is the only material disclosed in depth for the quantum well and barrier layers. In figure 6, the dark current behavior of an AlGaAs/GaAs QWC is shown, but no details of the cell are disclosed.

3. Claims 28, 29 and 30 are rejected under 35 U.S.C. 112, first paragraph, as containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. Claims 28 and 29 depend from claim 18, which recites the limitation "said substrate is InP" in line 4. Claim 28 recites the limitation "said substrate is GaSb" in line 1 and claim 29 recites the limitation "said

substrate is GaAs" in line 1. The specification does not describe how two substrate materials can be used in such a way as to enable one skilled in the art to make the claimed invention. The same applies to dependent claim 30.

4. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

5. Claims 1-17, 19, 20, 21-26, 28-30, 32, 34, 35 and 41 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claims 1, 6, 17, 19, 23, 32, 34 and 41 are indefinite because they contain limitations reciting the term "substantially." The range encompassed by the term "substantially" must be defined in the specification in order for the term to clearly define the claimed invention. For example, in claim 1 at lines 3-5, the limitation "a period...exerts substantially no shear force on a neighboring structure." On page 5 at lines 34-36, the specification discloses "the strain is compensated by choosing the material compositions and thickness of the layers in such a way that the average stress is zero." It is suggested that the term "substantially" be deleted from the claims. The same applies to dependent claims 2-17, 20, 25 and 26.

Claims 2 and 35 recite the limitation "the same lattice constant as a substrate" in line 4 of both claims. There is insufficient antecedent basis for this limitation in the claims.

Claims 4, 5, 21 and 22 are indefinite because it is not clear what is being claimed. For example, claim 4 recites "at least one of the tensile strained layers...is a quantum well...with a bandgap lower than if said quantum well had a lattice constant equal to said substrate lattice constant." If the quantum well had a lattice constant equal to the lattice constant of the substrate, the quantum well would necessarily have a different composition than the material used in the claimed structure. Since this material is not defined, it could arbitrarily be chosen from any material having a lattice constant equal to the lattice constant of the substrate. The same applies to dependent claims 7-9 and 24.

Claims 21 and 22 recite the limitation "said tensile strained layers or said compressively strained layers" in lines 1 and 2. There is insufficient antecedent basis for this limitation in the claims. The same applies to dependent claim 24.

Claims 28 and 29 depend from claim 18, which recites the limitation "said substrate is InP" in line 4. Claim 28 recites the limitation "said substrate is GaSb" in line 1 and claim 29 recites the limitation "said substrate is GaAs" in line 1. It is not clear how the substrate is two different materials. The same applies to dependent claim 30.

Claim Rejections - 35 USC § 102

6. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for a patent.

> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

7. Claims 1-6, 12 and 13 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Ekins-Daukes et al. disclose a solar cell having strain-balanced quantum wells, wherein the quantum wells contain alternating compressively strained InGaAs quantum wells and tensile strained GaAsP barriers, and "the dimensions were chosen to ensure the average lattice parameter across the *i* region <*a*> was equal to that of [the GaAs substrate]", i.e., the strain over each period is zero (p. 4195). Since the strain is zero over each period, each period exhibits zero shear force on neighboring structures, which includes a further period or the substrate.

Regarding claim 3, the recitation of the lattice constant of the substrate and the quantum wells inherently describes a crystalline device. A lattice constant is a measure of the distance between adjacent atoms in a regularly spaced arrangement, or crystal structure.

Regarding claims 4 and 5, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claim 6, a period of one quantum well and one barrier layer contains four elements: In, Ga, As and P.

Regarding claims 12 and 13, Ekins-Daukes et al. disclose the use of a GaAs substrate and InGaAs quantum well layers.

Since Ekins-Daukes et al. clearly teach the limitations recited in the instant claims, the reference is deemed to be anticipatory.

8. Claims 1-5, 7, 16 and 17 are rejected under 35 U.S.C. 102(a) as being anticipated by Rohr et al. ("STRAIN-BALANCED $In_{0.62}Ga_{0.38}As/In_{0.47}Ga_{0.53}As$ (InP) QUANTUM WELL CELL FOR THERMOPHOTOVOLTAICS", Conference Record of the 28th IEEE Photovoltaic Specialists Conference).

Rohr et al. disclose a thermophotovoltaic cell having strain-balanced quantum wells using InGaAs quantum wells and barriers (p. 1234). Rohr et al. disclose "the aim of strain-balancing is to reduce the average or effective stress to zero by balancing the forces of tensile and compressively strained layers" (p. 1234, Introduction). Therefore, each period of one quantum well layer and one barrier layer exerts no shear force on neighboring structures, such as further periods or the substrate.

Regarding claim 3, the recitation of the lattice constant of the substrate and the quantum wells inherently describes a crystalline device. A lattice constant is a measure of the distance between adjacent atoms in a regularly spaced arrangement, or crystal structure.

Regarding claims 4 and 5, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claim 7, the substrate is InP and the compressively strained layer is $In_{0.62}Ga_{0.38}As$.

Regarding claim 17, the bandgap of the quantum wells is less than the 0.73 eV.

Since Rohr et al. teach the limitations recited in the instant claims, the reference is deemed to be anticipatory.

9. Claims 1-6 and 12-14 rejected under 35 U.S.C. 102(a) as being anticipated by Ekins-Daukes et al. ("STRAINED AND STRAIN-BALANCED QUANTUM WELL DEVICES FOR HIGH-EFFICIENCY TANDEM SOLAR CELLS", Solar Energy Materials & Solar Cells).

Ekins-Daukes et al. disclose strain-balanced solar cells having quantum well layers and barrier layers that have compensating strains so that the strain between the quantum wells and the neighboring layers becomes zero (p. 77-78).

Regarding claim 3, the recitation of the lattice constant of the substrate and the quantum wells inherently describes a crystalline device. A lattice constant is a measure

of the distance between adjacent atoms in a regularly spaced arrangement, or crystal structure.

Regarding claims 4 and 5, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claims 6, 12 and 13, the substrate is GaAs and the quantum well and barrier layers comprise four elements: In, Ga, As and P (fig. 7).

Regarding claim 14, Ekins-Daukes et al. disclose the formation of the quantum wells on a virtual substrate having a virtual substrate lattice constant different from the substrate lattice constant (p. 82).

Since Ekins-Daukes et al. teach the limitations recited in the instant claims, the reference is deemed to be anticipatory.

Claim Rejections - 35 USC § 103

10. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

11. Claims 7-11, 14 and 15 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes t al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters) in view of Freundlich et al. (U.S. Pat. No. 5,851,310).

Ekins-Daukes et al. disclose a solar cell having the limitations recited in claims 1-6, 12 and 13 of the instant invention, as explained above in paragraph 7.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose the following:

a. The substrate is InP and the compressively strained layer is $In_xGa_{1-x}As$, where x>0.53, as recited in claim 7;

b. The substrate is InP and the tensile strained layer is $In_xGa_{1-x}As_{1-y}P_y$, where y>1, as recited in claim 8;

c. The tensile layer is GaInP, as recited in claim 9;

d. The substrate is InP and the quantum well is formed of layers of $Al_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 10;

e. The substrate is GaSb and the quantum well is formed of layers of $In_xGa_{1-x}As_ySb_{1-y}$, as recited in claim 11;

f. The quantum well portion is formed on a virtual substrate having a virtual substrate lattice constant different from the lattice constant of the substrate, as recited in claim 14; and

g. The virtual substrate is $InP_{1-y}As_y$, where 0<y<1, and the substrate is InP, as recited in claim 15.

Regarding claims 7-10 and 15, Freundlich et al. disclose a solar cell having an MQW with an InP substrate (fig. 1). The solar cells use InP because it has a high efficiency (col. 2, lines 30-41).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use an InP substrate as taught by Freundlich et al. because InP cells have a high efficiency.

Regarding claims 7-11, Freundlich et al. disclose that materials usable for fabricating the solar cells include InGaAs and "all alloys of indium gallium arsenide with the addition of iso-valent elements such as phosphorous, aluminum, and antimony in concentrations such that the lattice mismatch is less than 0.3 per cent compared to $In_{0.53}Ga_{0.47}As$" (col. 5, lines 26-39). Freundlich et al. further disclose a specific example using $In_xGa_{1-x}As$, where $0.48<x<0.55$ (col. 5, line 52).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use materials having the compositions taught by Freundlich et al. because Freundlich et al. teach that "these alloys have somewhat different energy bandgaps, which may be desirable in some applications" (col. 5, lines 32-33).

Regarding claim 11, Freundlich et al. disclose that "indium phosphide or other suitable materials well-known in the art may be used as a substrate" (col. 3, lines 58-59).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use other materials to form the substrate as taught by Freundlich et al. because different substrates can provide different desired properties.

Regarding claim 14, Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate as taught by Freundlich et al. because a virtual substrate helps "accommodate crystal lattice-matching requirements" between the different layers (col. 3, lines 58-62).

Regarding claim 15, Freundlich et al. disclose the use of alloys contained within the indium gallium arsenide series including phosphorous-containing alloys such as InAsP (col. 5, lines 26-39). The buffer layers are chosen to "accommodate crystal lattice-matching requirements" (col. 3, lines 58-62).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should

"accommodate crystal lattice-matching requirements", which would b accomplished by the choice of materials with similar properties.

12. Claims 16 and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ekins-Daukes t al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters) in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

Ekins-Daukes et al. disclose a solar cell having the limitations recited in claims 1-6, 12 and 13 of the instant invention, as explained above in paragraph 7.

The device of Ekins-Daukes et al. differs from the instant invention because Ekins-Daukes et al. do not disclose that the device is a thermophotovoltaic device and that the quantum wells have a bandgap equal to or less than 0.73 eV.

Freundlich et al. disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Ekins-Daukes et al. to use narrow bandgap quantum wells as taught by Freundlich et al. because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

13. Claims 18, 21-23 and 25-27 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310).

Freundlich et al. disclose the use of buffer layers (virtual substrates) "to accommodate crystal lattice-matching requirements between the sublayer and the top layer of the substrate" in MQW solar cells (col. 3, lines 58-62). Freundlich et al. also disclose the use of alloys contained within the indium gallium arsenide series, including phosphorous, aluminum and antimony alloys (col. 5, lines 26-39). The photovoltaic cell is formed on an InP substrate (fig. 1). Freundlich et al. further disclose that the alternating layers in the quantum well portion "are alternately in tensile and compressive strain...[to] reduce the overall strain magnitude in the heterostructure" (col. 7, lines 47-52).

Regarding claims 21 and 22, since the quantum well (or barrier) is made of a material having a specific lattice constant, any quantum well (or barrier) having the same lattice constant as the substrate would necessarily be made of a different material. Since the comparison material is not defined, the material can be chosen from an infinite number of material compositions having an equal lattice constant and differing bandgap.

Regarding claims 23, 25 and 26, the solar cell is formed on an InP substrate and the quantum well portion comprises four elements: In, Ga, As and P (col. 7, lines 54-55). The lattice constant of each period is the same as the adjacent periods (see Table

I). In the embodiment comprising an InAsP/InGaP quantum well system, the InGaP is the tensile strained layer (col. 7, lines 54-55).

Regarding claim 27, Freundlich et al. also disclose the use of GaAsSb in the formation of the solar cell (col. 5, lines 26-39).

The device of Freundlich et al. differs from the instant invention because Freundlich et al. do not disclose the use of an InAsP virtual substrate.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should "accommodate crystal lattice-matching requirements", which would b accomplished by the choice of materials with similar properties.

14. Claims 19, 20 and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310), as applied to claims 18, 21-23 and 25-27, and further in view of Ekins-Daukes et al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Freundlich et al. disclose a solar cell having the limitations recited in claims 18, 21-23 and 25-27 of the instant invention, as explained above in paragraph 13. Freundlich et al. further disclose that the alternating layers in the quantum well portion "are alternately in tensile and compressive strain...[to] reduce the overall strain magnitude in the heterostructure" (col. 7, lines 47-52).

The device of Freundlich et al. differs from the instant invention because Freundlich et al. do not disclose the following:

a. A period comprising a quantum well layer and a barrier layer exerts no shear stress on a neighboring structure, as recited in claim 19;

b. The neighboring structure is a further period, a layer of arbitrary doping, or the virtual substrate, as recited in claim 20; and

c. The compressively strained layer is InGaAs having a larger percentage of indium than the InGaAs composition having the same lattice constant as the virtual substrate, as recited in claim 24.

Regarding claims 19 and 20, Ekins-Daukes et al. teach strain-balancing the quantum well layers and the barrier layers in the solar cells so that no strain exists between the layers (p. 4195). This approach allows more quantum wells to be incorporated in the solar cell without causing strain relaxation (p. 4195).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to strain-balance the quantum well portion as taught by Ekins-Daukes et al. because balancing the strain within the quantum well portion allows more quantum wells to be used, thus increasing the efficiency of the solar cell.

Regarding claim 24, Ekins-Daukes et al. disclose the use of compressively strained InGaAs layers (p. 4195). Since the layer is compressively strained, the lattice constant is greater than the other layers including the virtual substrate. A layer of

InGaAs with a lattice constant the same as the virtual substrate would have a lower concentration of indium.

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use compressively strained InGaAs layers as taught by Ekins-Daukes et al. because InGaAs quantum wells have been shown by Ekins-Daukes et al. to increase the conversion efficiency of conventional solar cells.

15. Claims 31-33 and 36-41 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310), as applied to claims 18, 21-23 and 25-27, and further in view of Freundlich et al. (U.S. Pat. No. 6,150,604).

In US '310, Freundlich et al. disclose a solar cell having the limitations recited in claims 18, 21-23 and 25-27 of the instant invention, as explained above in paragraph 13.

The device of Freundlich et al. (US '310) differs from the instant invention because Freundlich et al. do not disclose the following:

a. The device is a thermophotovoltaic device, as recited in claims 31 and 40;

b. The quantum wells have a bandgap of 0.73 eV or less, as recited in claims 32 and 41;

c. The quantum well is comprised of alternating layers of $In_xGa_{1-x}As$, where $x>0.53$, and barrier layers of $Ga_yIn_{1-y}P$, where $y>0$, as recited in claim 33; and

d. The virtual substrate is InPAs, as recited in claim 39.

Regarding claims 31, 32, 40 and 41, Freundlich et al. (US '604) disclose a MQW thermophotovoltaic solar cell having a bandgap of 0.49-0.74 eV (Table III). The narrow bandgap quantum wells "allows for more efficient conversion of the IR emission emanating from a black body or selective emitter over a wider range of wavelengths than a conventional single junction cell and decreases transparency losses of the conventional cell" (col. 2, lines 40-45).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. (US '310) to use narrow bandgap quantum wells as taught by Freundlich et al. (US '604) because narrow bandgap quantum wells "allows for more efficient conversion of the IR emission" (col. 2, lines 40-45).

Regarding claim 33, Freundlich et al. (US '310) disclose the use of alloys contained within the indium gallium arsenide series, including phosphorous, aluminum and antimony alloys (col. 5, lines 26-39). The photovoltaic cell is formed on an InP substrate (fig. 1). In one embodiment, Freundlich et al. disclose an InAsP/InGaP quantum well system, the InGaP is the tensile strained layer (col. 7, lines 54-55).

Freundlich et al. (US '604) disclose the use of InGaAs wells under compressive strain, with a specific example of wells comprising $In_{0.9}Ga_{0.1}As$ (col. 5, line 9).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. (US '310) to use a

compressively strained InGaAs layer having a high indium concentration as taught by Freundlich et al. (US '604) because an InGaAs layer with a high indium concentration has a narrower bandgap, which increases the absorption of the IR regions.

Regarding claim 39, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. to use a virtual substrate of InPAs because Freundlich et al. teach that the solar cell can be made of many different alloys depending on the desired bandgaps and the buffer layer should "accommodate crystal lattice-matching requirements", which would b accomplished by the choice of materials with similar properties.

16. Claims 34 and 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Freundlich et al. (U.S. Pat. No. 5,851,310) in view of Freundlich et al. (U.S. Pat. No. 6,150,604), as applied above to claims 31-33 and 36-41, and further in view of Ekins-Daukes t al. ("STRAIN-BALANCED GaAsP/InGaAs QUANTUM WELL SOLAR CELLS", Applied Physics Letters).

Freundlich et al. (US '310 and US '604) disclose a solar cell having the limitations recited in claims 31-33 and 36-41 of the instant invention, as explained above in paragraph 15.

The device described by US '310 and US '604 differs from the instant invention because they do not disclose that a period of one tensile strained layer and one compressively strained layer exerts no shear force on a neighboring structure.

Ekins-Daukes et al. teach strain-balancing the quantum well layers and the barrier layers in the solar cells so that no strain exists between the layers (p. 4195). This approach allows more quantum wells to be incorporated in the solar cell without causing strain relaxation (p. 4195).

It would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Freundlich et al. (US '310 and US '604) to strain-balance the quantum well portion as taught by Ekins-Daukes et al. because balancing the strain within the quantum well portion allows more quantum wells to be used, thus increasing the efficiency of the solar cell.

Conclusion

17. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Ekins-Daukes et al. ("STRAIN-BALANCED MATERIALS FOR HIGH-EFFICIENCY SOLAR CELLS", Conference Record of the 28th IEEE Photovoltaic Specialists Conference) discloses the method of strain-balancing layers in MQW structures.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Brian L. Mutschler whose telephone number is (703) 305-0180. The examiner can normally be reached on Monday-Friday from 8:00am to 4:30pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nam Nguyen can be reached on (703) 308-3322. The fax phone numbers

for the organization where this application or proceeding is assigned are (703) 872-9310 for regular communications and (703) 872-9311 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 308-0661.

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